Damage by the 2011 Great East Japan earthquake

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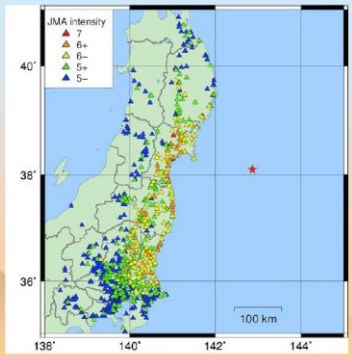
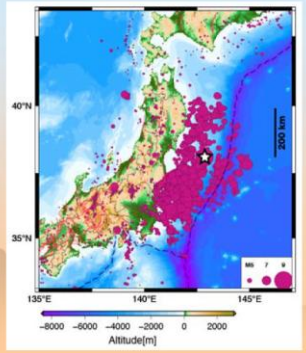
Epicenter and JMA SI

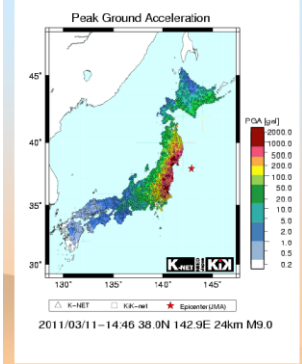


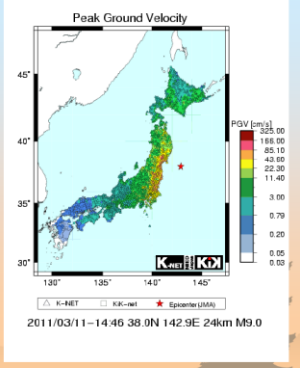
Aftershocks



2011年3月11日から3月27日までの余震分布

Peak Ground Acc. and Vel. (1)





After NIED

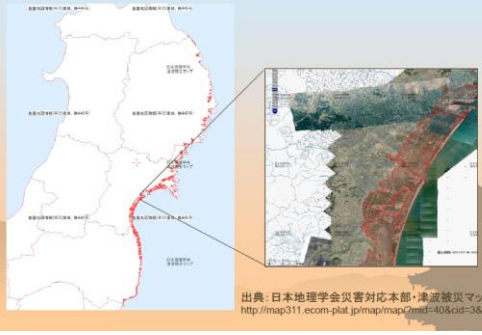
Peak Ground Acc. and Vel.

Large PGA observed sites

	Site Name	Site Code	PGA (cm/s/s)	PGV (cm/s)
1	K-NET Tsukidate	MYG004	2,933	106
2	K-NET Siogama	MYG012	2,019	64
3	K-NET Hitachi	IBR003	1,845	74
4	K-NET Sendai	MYG013	1,808	83
5	K-NET Hokota	IBR013	1,762	71
6	K-NET Imaichi	TCG009	1,444	48
7	K-NET Shirakawa	FKS016	1,425	63
8	KiK-net Nishigou	FKSH10	1,335	41
9	K-NET Oomiya	IBR004	1,312	47
10	KiK-net Haga	TCGH16	1,305	82

PGA and PGV : Vectorial Summation of 3 Components
Bandpass filter to calculate velocity waveform : 0.1-15Hz

Damaged area by tsunami



出典：日本地理学会災害対応本部・津波被災マップ
http://map311.ecom-plat.jp/map/map?mid=40&cid=3&gid=0

Great tsunami hit residential area.

3月11日15：55撮影：共同通信社ヘリ

Damage to houses

Overturn of building

Wash away and overturn of building

Most of RC buildings were not damaged severely even in coast area.

Characteristics of damage

- Earthquake : Ground shaking
  Ground failure (Liquefaction, Slope failure, etc.)
- Tsunami : Inundation
  Washing away
  Scouring

Damage by ground shaking and liquefaction

Tsunami (Washing away)

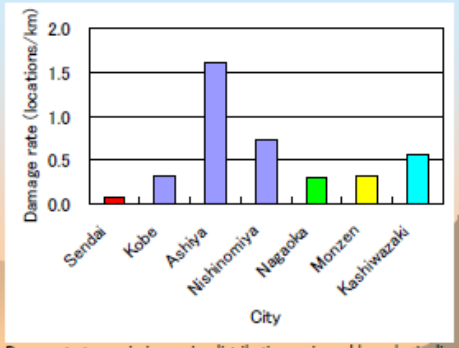
Tsunami (Inundation)

Damage by tsunami (Scouring and washing away)

No damage to earthquake-proofing pipe

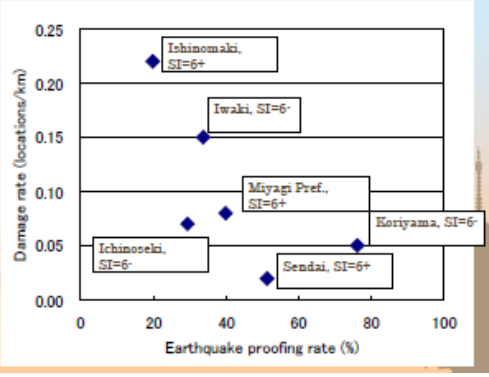
No damage to earthquake-proofing pipe

Comparison of damage rate



Damage to transmission main, distribution main and branch pipelines

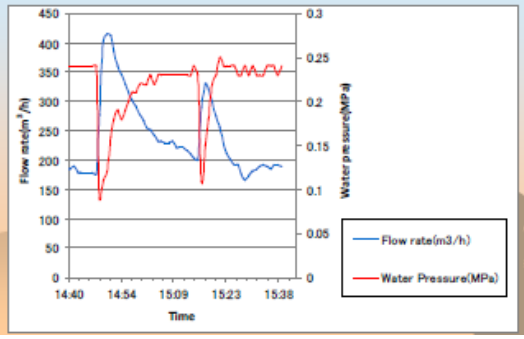
Earthquake proofing rate and damage rate



Characteristics of damage to water supply facilities

- Damage to aged pipelines with small diameter
- Damage to air valves
- No damage to earthquake-proofing pipeline
- Malfunction of purification plants in flooded area

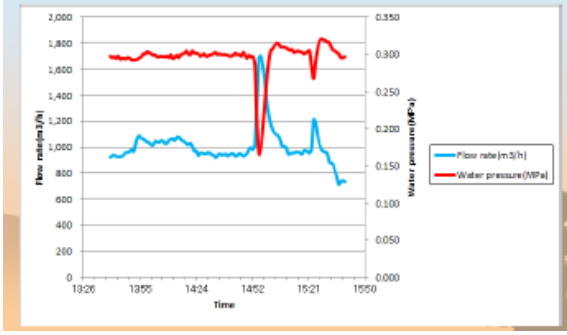
Flow rate and water pressure at a water distribution plant of Tokyo



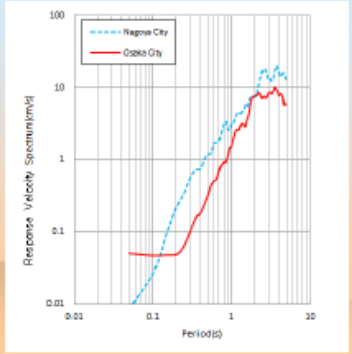
Occurrence of the unusual phenomena of water distribution system

Name	Seismic Intensity	Occurrence
Sapporo City	3	N/A
Aomori City	4	N/A
Morioka City	5+	N/A
Akita City	5+	N/A
Sendai City	6−	Yes
Yamagata City	4	Yes
Niigata City	4	N/A
Mito City	6−	N/A
Utsunomiya City	5+	Yes
Chiba Prefecture	5+	Yes
Tokyo Metropolitan	5−	Yes
Saitama City	5+	Yes
Yokohama City	5+	N/A
Kofu City	5−	N/A
Nagoya City	4	Yes
Kanazawa City	3	N/A
Osaka City	3	Yes
Kobe City	2	N/A
Hiroshima City	1	N/A

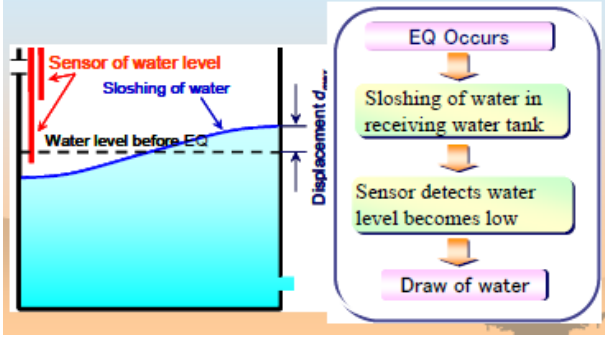
Flow rate and water pressure at a water distribution plant of Osaka



Response velocity spectra at Nagoya and Osaka



Mechanism of draw of water



Predominant period of water in receiving water tank

$$Ts = \frac{2\pi}{1.58\frac{g}{l}\tanh\left(1.58\frac{h}{l}\right)}$$

where,

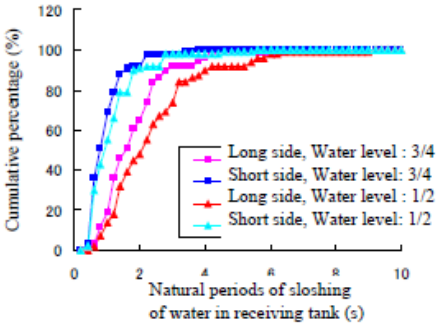
Ts : Predominant period of sloshing (s)
g : Acceleration of gravity (m/s²)
h : Depth of water (m)
l : 1/2 of length of basement (m)

Maximum displacement of water caused by sloshing

$$d_{max} = \frac{0.527l\coth\left(1.58\frac{h}{l}\right)}{\frac{g}{\omega^2\theta_h l}-1} \qquad \theta_h = 1.58\frac{S_v}{\omega\, l}\tanh\left(1.58\frac{h}{l}\right)$$

g : Acceleration of gravity (m/s²)
h : Depth of water (m)
l : 1/2 of length of basement (m)
S_v: Response velocity spectrum of predominant period of sloshing (m/s)
ω :Predominant circular frequency

Predominant period of water in receiving water tank



Concluding remarks (1)

- The entire damage to water supply pipelines is not revealed in flooded areas by tsunami. We must collect all damage data and analyze it to learn the lessons from this disaster.
- Effect of earthquake-proofing for pipeline was verified. We must accelerate the earthquake proofing, especially for aged facilities.
- Force of tsunami acted on a buried pipe is not clear. The effect of tsunami must be studied soon.

Concluding remarks (2)

- If sloshing of water in receiving water tank is occurred by an earthquake, draw of water to receiving water tank from pipeline starts by error of sensor of water level in the receiving water tank. Sloshing of water in receiving water tank, therefore, seems to be one of the causes of unusual phenomena.